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THE RELATIONSHIP BETWEEN VEGETATION, SOIL TEXTURE, NUTRIENT STATUS AND HERBICIDE TREATMENTS ON TRANSMISSION RIGHTS-OF-WAY IN THE VICINITY OF ESSA TS, GEORGIAN BAY REGION

Report No 88-211-K

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ABSTRACT

The vegetation on several transmission rights-of-way in the Georgian Bay Region was surveyed during the summer of 1987 to determine the response of plant communities to operational herbicide treatments. The distribution of these communities was related to the elapsed time since herbicide treatment, soil factors (texture, nutrients, pH) and a north-south gradient.

job	file	date	report no.
34-566-031	834.1	November 11, 1988	88-211-K

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EXECUTIVE SUMMARY

THE RELATIONSHIP BETWEEN VEGETATION, SOIL TEXTURE, NUTRIENT STATUS AND HERBICIDE TREATMENTS ON TRANSMISSION RIGHTS-OF-WAY IN THE VICINITY OF ESSA TS, GEORGIAN BAY REGION

D. Brown
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Chemical Research Department

In the early 1970's, Ontario Hydro shifted its vegetation control policy from a non-selective treatment of all species to a selective treatment of certain target species to promote the development and spread of low maintenance communities. An uncertain parameter in the selective treatment policy is the definition of a target species. Plants which tend to stimulate the establishment of tree seedlings should be removed, while growth of species or communities which are able to out-compete trees should be encouraged. This project was undertaken to observe changes in vegetation following selective herbicide treatments of an operational right-of-way.

Six different communities were identified from the 161 quadrats analyzed at 14 sites near Essa TS, Georgian Bay Region. Four of the communities were recurrent while the other two were restricted to only one site. A preliminary analysis of the environmental variables associated with each community indicated that the quadrats which formed community 6 were the most distinctive: with basic soils of low sand content and high concentrations of calcium, magnesium and nitrate. Community 5 vegetation tended to be found at the more northerly sites, with acidic sandy soils and high organic contents. Community 4 vegetation was found in areas with high concentrations of organic matter, calcium and nitrate. Communities 1, 2 and 3 were found on slightly acidic soils with low organic contents. The soils from the community 3 quadrats had high levels of potassium and phosphate.

Vegetation communities 1, 2 and 3 were found more often on the recently treated rights-of-way, while the older rights-of-ways had vegetation types 4 and 5. However, a larger degree of site replication would be required to determine if successional or cyclic trends existed as a response to the herbicide treatments. It is possible that the vegetation composition is more affected by the herbicide used rather than the time interval following the treatment. Ordination results provided a preliminary indication that Krenite (fosamine-ammonium) had a different effect on the vegetation than either 2,4 D/DP or picloram (Tordon).

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Fifty of the 161 quadrats on the right-of-way contained at least 1 stem of an incompatible tree species, corresponding to a frequency of 31%, and a minimum estimated density of 1 stem m^{-2}. Chi-square analysis indicated that the occurrence of these trees was not statistically affected by the type of vegetation community ($X^2 = 5.552$, $p = 0.35$) or the number of years since the lines were last treated (Table 10, $X^2 = 4.509$, $p = 0.341$). Thus it appears that the right-of-way is rapidly invaded following the herbicide treatment. However, it cannot be determined from this study which, if any, of these communities may form a desirable cover. A study designed to better quantify the resistance of these communities to invasion by incompatible species is currently underway.

A survey of the literature also suggests that the occurrences of natural plant communities with the ability to inhibit tree invasion or growth are highly fortuitous. Even with extensive selective maintenance, their creation is a highly elusive goal (Jotcham 1985). With the exception of a few isolated communities, all of the rights-of-way would most likely revert to a tree cover if left unmanaged for several years, due to the continuous pressure exerted on the area from the surrounding woodlands. This process may be delayed by the dense plant growth encouraged by a selective herbicide control policy (Bramble and Byrnes 1983), but it cannot be prevented entirely. Alternatively, the natural vegetation could be replaced by the planting of a cover (smother) crop selected for its ability to inhibit incompatible trees. The difficult task which confronts the vegetation control manager is to select an appropriate combination of the available chemical, mechanical and biological controls which provides an optimum balance of cost, environmental acceptability and vegetational stability.

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To: Dr. D. Mills
Director of Research

THE RELATIONSHIP BETWEEN VEGETATION, SOIL TEXTURE, NUTRIENT STATUS AND HERBICIDE TREATMENTS ON TRANSMISSION RIGHTS-OF-WAY IN THE VICINITY OF ESSA TS, GEORGIAN BAY REGION

1.0 INTRODUCTION

In an unmanaged state, the vegetation on a right-of-way will develop towards a stable, climax community. In Ontario, this climax is usually a forest, which represents a very hazardous situation for a transmission or distribution line. Continued disturbance of the right-of-way is required to setback the successionary process leading towards the forest.

In the early 1970's, Ontario Hydro shifted its vegetation control policy from a non-selective treatment of all species to a selective treatment of certain target species. The theory behind this change was to develop a plant community that was resistant to the invasion of the tall growing, incompatible tree species by successively removing the target species without disrupting the remaining vegetation cover. This new community would have some inherent ability to resist or slow down the successional process (Niering and Egler 1955, Egler 1958). The ultimate goal of this management is to induce a pseudo-stable community which requires minimal upkeep in both the number of treatments required and the time commitment for each individual treatment. All tall growing trees must be removed to ensure safety of the lines, which sets the minimum criterion for a target species. However, to encourage the development and spread of low maintenance communities, species of plants which tend to stimulate the establishment of tree seedlings should be removed, while growth of species which are able to out-compete trees should be encouraged. Studies on the changes in vegetation over time (succession) are thus necessary to better define what constitutes a target species or community.

Little is known about the dynamics of right-of-way communities in this province (Welch 1983), therefore a project was initiated by the Research Division to identify existing plant communities and to describe the pattern of vegetational change between treatment cycles on operational transmission rights-of-way.

2.0 METHODS

2.1 Site Selection

The location selected for the study was the area surrounding Essa TS, Georgian Bay Region. This was chosen since it contains several transmission corridors under staggered treatment schedules within a 25 km radius of the station. This allowed for the selection of several research sites differing in the elapsed time since the herbicide treatment, but with similar climatic and climax vegetation characteristics.

Potential sites were selected from aerial photographs and data contained in the regional Transmission Environment Profile. The primary criterion for site selection was the presence of a natural woodlot (not a plantation) on both sides of the right-of-way. A field survey of these sites was conducted in May, 1987. Observations on terrain, composition of the woodlot, degree of human disturbance and soil moisture conditions were taken. Final site selection was based on the following criteria: 1) A woodlot must be present on both sides of the right-of-way, 2) No standing water, and 3) The terrain must be relatively flat and uniform. A total of 12 sites met these criteria (Figure 1, Table 1), 3 had been treated in 1986 (year 1), 5 in 1985 (year 2), 2 in 1984 (year 3), 1 in 1982 (year 5) and 1 site was located under an idle line which had not been treated since 1975. Two additional sites (T634, P33), originally discarded due to marshy ground, were added to provide additional replications for the year 3 and year 5 treatments respectively.

The vegetation at each site was analyzed using local frequency in a 1 m x 1 m quadrat. Each quadrat was subdivided into 25 sections; local frequency was reported as the number of occurrences out of 25. All vegetation except mosses were included in the survey. Due to identification problems, grasses and sedges were only recorded if an inflorescence was present. The quadrats were located at 10 m intervals on transects running perpendicular to the right-of-way. The transects were extended such that 1 quadrat was located in the woods on either side of the right-of-way. For those sites under the 500 kv transmission lines (T835, T738, T698, T634), only the west line was sampled, with 2 quadrats located in the woods on the west side. Two transects were run at most sites, normally located 50 m on either side of the tower, unless it was necessary to avoid excessively wet areas and roadways. A third transect, located 100 m from the tower, was analyzed at T835, T255 and T634. Taxonomy of herbaceous vegetation follows Fernald (1950); woody vegetation follows Soper and Heimburger (1982) and Hosie (1979). A complete species list is included as Appendix A.

One 6 cm x 12 cm soil core was taken from each quadrat for analysis. These were sent to the Department of Land Resource Science, University of Guelph, for determination of nutrients (phosphate, potassium, magnesium, calcium, nitrate), pH, organic matter content and particle size fractionation.

2.2 Data Analysis

An ordination technique is based on the underlying theory that each piece of vegetation is unique. Quadrats are located in an n-dimensional space based on floristic composition (where n is the total number of species in all samples). New ordination axes are then derived to best represent the spatial arrangement of the quadrats, reducing its complexity to a few (1-4) dimensions which attempt to display the major relationships or gradients in the data set. Quadrats which are placed in close proximity on the ordination plot will be composed of similar species, while samples which are far apart on the plot will have few, if any, species in common. Several different ordination algorithms exist, each differing in the way the axes are derived, the

Table 1

A description of the treatment history of the sites included in this study

Line	Tower	Treatment Years	Most Recent Herbicide
NA C9x22	T45	1984	2,4D/DP
NA 18xC9	T32	1976	
		1980	
		1986	Krenite
	T27	1976	
		1980	
		1986	Krenite
G 68x2	P150	1980	
		1985	2,4D/DP
	P123	1977	
		1982	Krenite
G 18x13	P33	1977	
		1982	Krenite
NK 33x18 -01	T738	1979	
		1985	2,4D/DP
	T698	1978	
		1984	Tordon
	T634	1978	
		1984	Tordon
NA 92x18	T369	1976	
		1980	
		1986	Krenite
	T301	1980	
		1985	Tordon
	T255	1980	
		1985	Tordon
NK 18x51	T835	1979	
		1985	2,4D/DP
G 18x88	T23	1975	

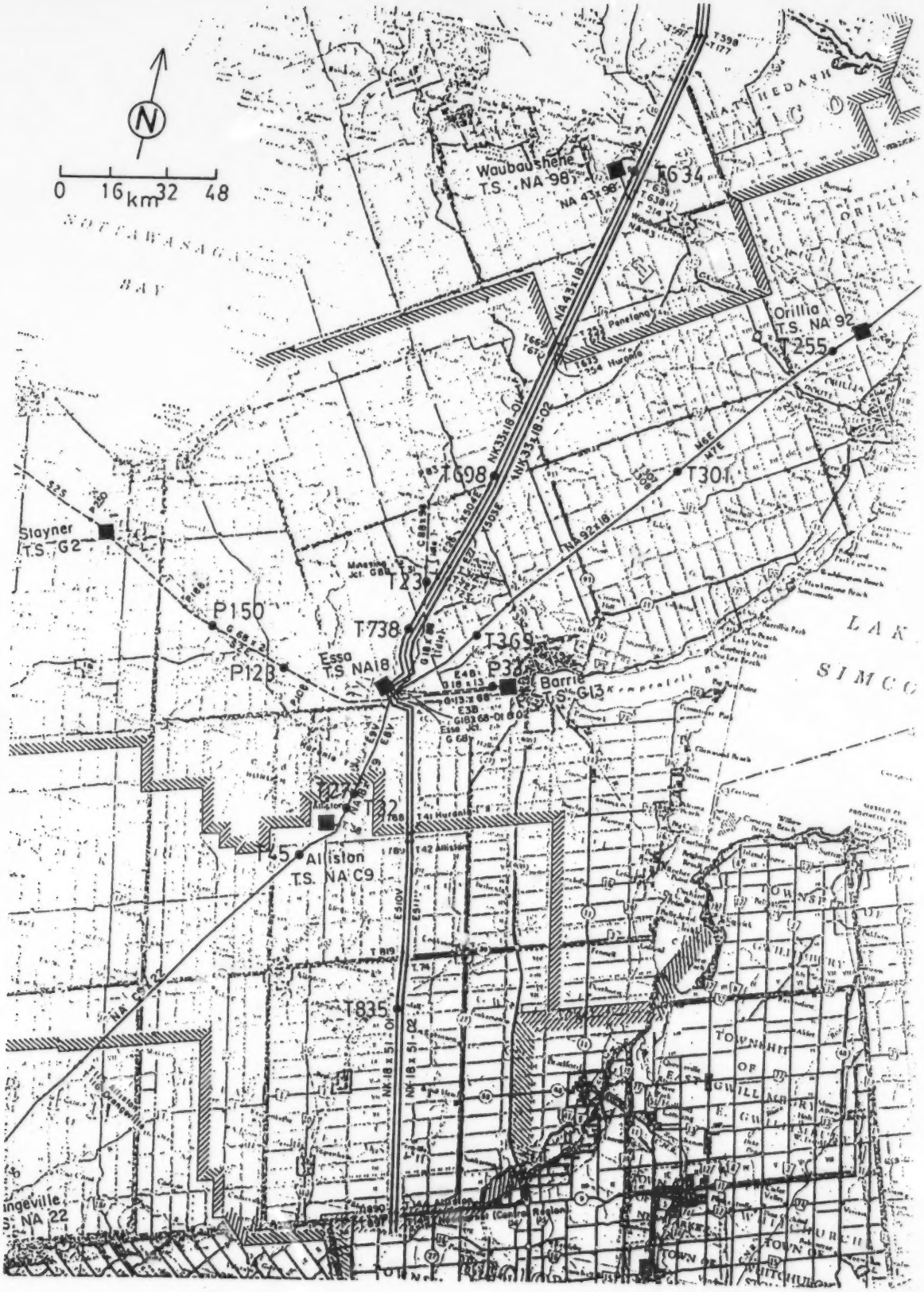

FIGURE 1

A MAP OF THE TRANSMISSION SYSTEM IN THE BARRIE AREA SHOWING THE LOCATIONS OF THE SITES USED IN THIS STUDY.

statistical assumptions involved in the calculation, and in the degree of distortion produced by the dimension-reduction. Two different techniques were investigated in this project, detrended correspondence analysis (DCA) (program DECORANA, Hill 1979a, Hill and Gauch 1980) and non-metric multidimensional scaling (program MDSCAL, Orloci and Kenkel 1985). The DCA analysis generated the most ecologically explainable results, thus the majority of the analysis will concentrate on this technique.

A classification is based on the premise that recurring units of vegetation exist, and the differences within these natural groupings is unimportant when compared to the differences between the classes. Two-way indicator species analysis (program TWINSPAN, Hill 1979b) is considered to be one of the more effective classification procedures currently available (Kershaw and Looney 1985). This is a hierarchial, divisive, polythetic method based on a correspondence analysis ordination. For each division, the algorithm performs a 1 dimensional ordination, splits this into two halves and determines which species show a preference to one half over the other. This information is then used as a weighting in a second, improved ordination, which is used to divide the data set into two classes. A small group of species which most strongly prefers one class over the other are then chosen as indicator species for that division. This process is repeated for each resulting class until a minimum class size is reached. TWINSPAN is not able to use quantitative data, but uses "Pseudospecies" as dummy variables to indicate differences in local frequency. Local frequencies of 0, 3, 6 and 12 were used to define the pseudospecies cut levels.

Two quadrats from the woods at P123 contained no vegetation, and the initial DCA ordination of the complete data set indicated 3 quadrats from a swampy area along the third transect at T634 were outliers. These 5 quadrats were deleted from the data set for all analysis. For detailed analysis of the right-of-way vegetation, quadrats situated in the woods and the edge of the right-of-way were removed, leaving 161 samples.

ANOVA procedures were used to investigate the possibility of relationships between the TWINSPAN classes and the environmental parameters. A chi-square analysis (program STATGRAGHICS (STSC Inc)) was used to investigate associations between incompatible trees and the TWINSPAN vegetation classes and individual species of herbaceous vegetation.

Three methods were used to study the relationships between the derived DCA axes and the environmental data: Spearman's rank correlations between the DCA axes and environmental data (STATGRAGHICS (STSC Inc)), a subjective analysis of scattergrams which overlay the environmental data on the DCA ordination plot, weighted averages ordination (ORDIFLEX (Gauch 1977)). Weighted averaging represents a relatively simple secondary ordination technique which has been used to interrelate environmental and vegetational data (Gauch 1977, Gauch and Stone 1979). The quadrat scorings from the primary DCA ordination, which represent a complex synthesis of the ecological information affecting the distribution of the vegetation, are used as weightings in a secondary ordination of the environmental data. This may be superimposed on the primary DCA plot to indicate relationships between the environmental data and the vegetation data. To better display the gradients in the data, each continuous environmental variable was divided into three discontinuous pseudovariables (*sensu* Hill 1979b) of low, low-medium and low-medium-high (Table 2), and the values within each pseudovariable were scaled from 1 to 100. The treatment year variable was divided into 5 pseudovariables.

Components of community structure were also calculated for each quadrat. The number of species in each quadrat was used as an estimate of species richness (S). The Shannon index was used to estimate species diversity ($H = -\Sigma\ Ni/N \log Ni/N$, where Ni is the local frequency of each species, and N is the total local frequency of all species in the quadrat), and evenness was calculated as $E = H/\log S$ (Odum 1971).

Table 2

Ranges used in defining the pseudovariables for the combined weighted averages ordination of vegetation and environmental variables

Variable	Pseudovariable[a]		
	1	2	3
Distance (km)	0-9.6	0-12.8	0-27
phosphate (µg/mL)	0-4.9	0-10.9	0-65
potassium (µg/mL)	0-44.9	0-99.9	0-800
nitrate (µg/g)	0-1.9	0-6.9	0-100
calcium (µg/g)	0-500	0-2000	0-111000
magnesium (µg/g)	0-49.9	0-100	0-800
pH	3.5-4.9	3.5-6.5	3.5-8
organic matter (%)	0-4.9	0-20	0-86
sand (%)	0-69	0-85	0-100
silt (%)	0-9.9	0-24.9	0-84
clay (%)	0-4.9	0-9.9	0-35

[a] Each pseudovariable was was standardized in the range 0-100 prior to analysis. Five pseudovariables were used to represent each treatment year.

3.0 RESULTS

3.1 Vegetation structure and relationships with environment

The DCA plot of the 225 right-of-way and wood quadrats is shown in Figure 2. The ordination broadly divides the quadrats into two groups. If a diagonal is drawn from the upper left to the lower right corner, quadrats located on the right-of-way tend to fall below, and quadrats from the adjacent woodlots tend to fall above the diagonal. This separation reflects the large difference in vegetational composition expected between the open environment of the right-of-way and the closed canopy conditions in the woodlands. However, the wide distribution of the wooded sites on DCA axis 1 indicates there is substantial variation in these quadrats. As it is thought that the vegetation on the right-of-way, if left untreated, would converge towards the adjacent woodland (Bramble and Byrnes 1983, Thibodeau and Nickerson 1986), this variance suggests that the directional forces operating at each site differs. The TWINSPAN classification of this data set (Figure 2 insert) separated the southern most site (T835) at the first division, and then separated the right-of-way from the wooded quadrats on the second division. This is a preliminary indication that a north-south gradient may also be an important influence on the vegetation distribution.

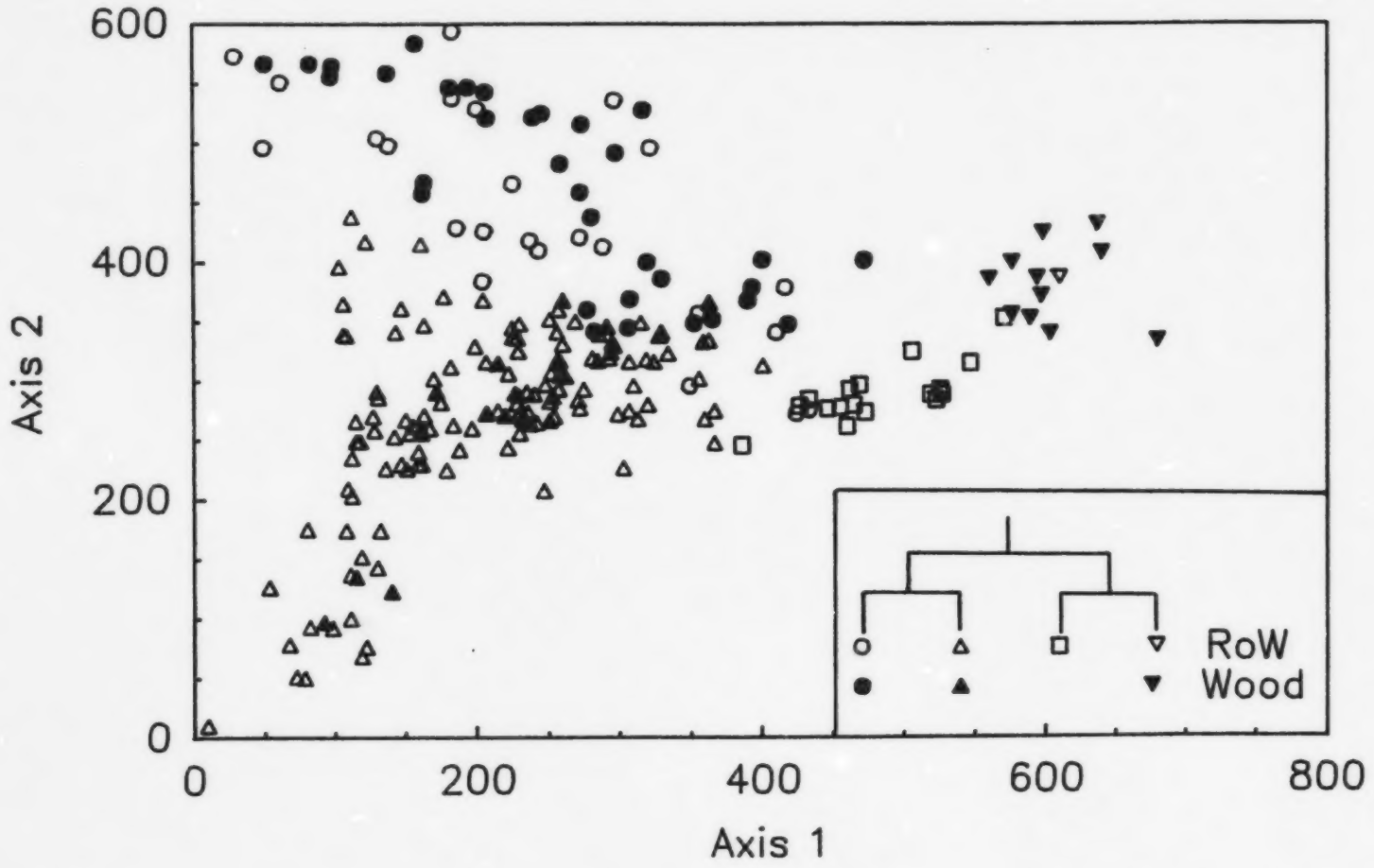

FIGURE 2

THE FIRST TWO AXES OF THE DCA ORDINATION OF THE 225 QUADRATS LOCATED ON THE RIGHT-OF-WAY (OPEN) AND ADJACENT WOODLOTS (CLOSED). INSERT SHOWS THE FIRST TWO TWINSPAN DIVISIONS FOR THE SAME DATA, WHICH CREATED FOUR CLASSES DENOTED BY CIRCLE, SQUARE, UP TRIANGLE AND DOWN TRIANGLE. THE T835 QUADRATS COMPOSE THE MAJORITY OF THE SQUARE AND DOWN TRIANGLE CLASSES.

Classification of the 161 right-of-way quadrats placed them in 6 distinct groups (Figure 3) based on their floristic composition. The first division separated T835 quadrats as class 6. Indicator species for this division was the absence of *Fragaria virginiana*, the presence of moderate amounts of *Geum* sp. (local frequency above 3) and an unidentified thistle. The remaining quadrats underwent three additional divisions before the classes were finalized. The second division, with *Rumex acetosella*, *Viola* sp., *Solidago rugosa* and *Onoclea sensibilis* as indicator species, separated classes 1,2 and 3 from 4 and 5. The third division isolated 18 quadrats from T32, P150 and P33 as class 1. The presence of *Chrysanthemum leucanthemum* (local frequencies above 3), *Equisetum arvense*, *Potentilla recta* and *Oxalis montana* and the absence of high levels of *Fragaria virginia* (local frequency over 3) were the best indicators. The fourth level of division placed 29 quadrats into class 2 (T301, T32, T634 and transect 1 of T738) and 13 quadrats into class 3 (T369), with *Pteridium aquilinum*, *Convolvulus spithamaeus* and *Aster schreberi* as positive indicators for class 3. Classes 4 and 5 were formed on the third level, with *Taraxacum officinale* as a positive indicator for the 41 class 5 quadrats, and *Aster lowrieanus*, high levels of *Solidago* sp. (local frequency above 6), *Geum* sp., *Cerastium vulgatum*, *Geranium* sp. and *Equisetum arvense* (above local frequency of 6) as positive indicators for class 4. This class primarily consisted of quadrats from T23, T27, T45, P123, and the second transect of T738, while class 5 vegetation was found at T698, P33, T255 and T634.

A preliminary ANOVA study of the environmental variables associated with each vegetation class (Table 3) indicated that the quadrats which formed class 6 were the most distinctive, with alkaline soils of low sand content and high concentrations of calcium, magnesium and nitrate. The class 5 vegetation tended to be found at the more northerly sites, with acidic sandy soils and high organic contents. Class 4 vegetation was found in areas with high concentrations of organic matter, calcium and nitrate. Classes 1, 2 and 3 were found on slightly acidic soils with low organic content, and tended to be found on the more recently treated sites. The soils from the class 3 quadrats had high levels of potassium and phosphate.

The relationships between quadrats is displayed by the DCA ordination in Figure 4. This plot has the TWINSPAN groupings overlaid. It can be observed that the first two levels of the TWINSPAN division separated the samples along DCA axis 1, while the third and fourth divisions separated the quadrats along the second axis. All 6 classes could be separated on DCA axes 1 and 2, while axis 3 indicated a high degree of similarly between classes 4 and 5, in addition to a degree of overlap between classes 1 and 2.

The correlation matrix between the first four DCA axes and the environmental data is given in Table 4. It can be seen that the first axis is strongly related to soil characteristics, especially organic matter content, calcium, magnesium, and soil texture. Soil pH was correlated to both the first and second axis. DCA axis 2 was also strongly correlated to a north-south gradient, represented by the distance the quadrats are north of T835. A high correlation was also indicated between nitrate and axis 1 and calcium and axis 2, however observation of the scatterplots indicated that these were spurious correlations. Axis 3 was not strongly correlated to any of the measured parameters, while axis 4 was correlated to soil pH.

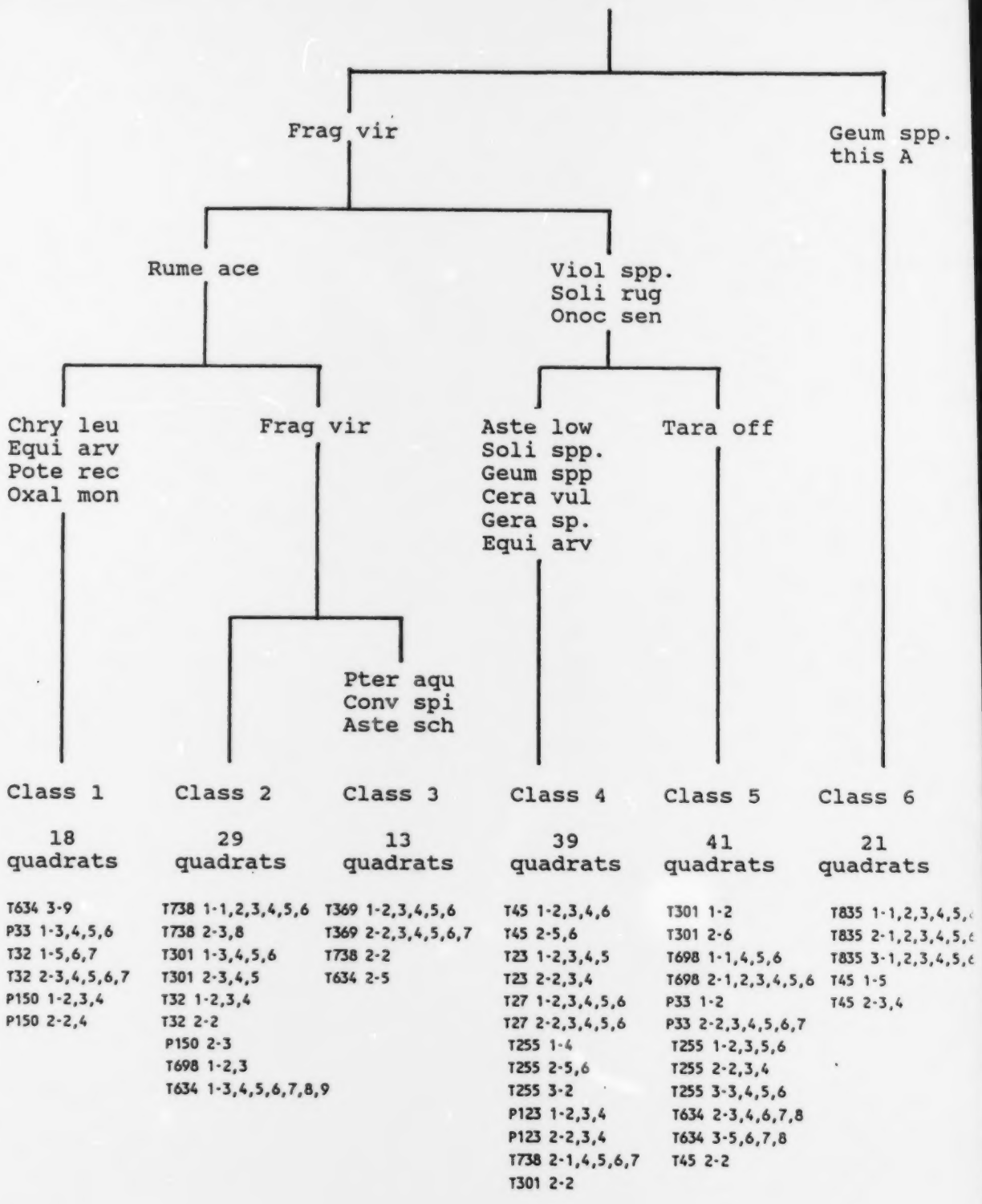

FIGURE 3

THE TWINSPAN CLASSIFICATION OF THE 161 QUADRATS LOCATED ON THE RIGHT-OF-WAY. INDICATOR SPECIES ARE GIVEN FOR EACH DIVISION, USING THE FIRST 4 LETTERS OF THE GENUS AND FIRST 3 LETTERS OF THE SPECIES NAME. THE QUADRATS COMPRISING EACH CLASS IS GIVEN AT THE BOTTOM OF THE FIGURE.

Table 3

A summary of the environmental data associated with each TWINSPAN vegetation class

Variable	Class	Sample Size	Mean	Standard Error	Min	Max	ANOVA MRT[1]	F
treatment	1	18	2.2	0.37	1.0	5.0	ab	6.181
year	2	29	2.1	0.12	1.0	3.0	ab	
	3	13	1.2	0.16	1.0	3.0	a	
	4	39	3.6	0.45	1.0	9.0	c	
	5	41	3.0	0.16	2.0	5.0	bc	
	6	21	2.1	0.08	2.0	3.0	ab	
distance	1	18	9.1	1.17	5.7	26.8	b	36.23
km north	2	29	16.2	1.33	5.7	26.8	cd	
of T835	3	13	12.2	1.21	11.0	26.8	bc	
	4	39	10.2	0.87	4.0	22.8	b	
	5	41	19.1	0.96	4.0	26.8	d	
	6	21	0.6	0.31	0.0	4.0	a	
potassium	1	18	48	6	19	107	a	8.416
µg/ml	2	29	66	6	14	146	a	
	3	13	199	68	62	924	b	
	4	39	58	9	12	325	a	
	5	41	45	3	19	112	a	
	6	21	98	13	15	297	a	
phosphate	1	18	11	1	2	28	ab	33.537
µg/ml	2	29	9	1	3	32	ab	
	3	13	37	5	4	65	c	
	4	39	5	0	2	20	a	
	5	41	5	1	2	50	a	
	6	21	16	1	3	29	b	
magnesium	1	18	30	1	18	41	a	10.89
µg/ml	2	29	78	8	26	182	a	
	3	13	61	8	20	138	a	
	4	39	193	36	28	795	b	
	5	41	81	10	15	328	a	
	6	21	246	21	54	412	b	
calcium	1	18	875	271	172	3962	a	39.678
µg/g	2	29	1177	159	204	3177	a	
	3	13	728	172	126	2198	a	
	4	39	3871	517	278	10190	b	
	5	41	938	114	89	2791	a	
	6	21	6893	472	1610	11100	c	

1 95% confidence interval Multiple Range test.
a, b, c indicate means which are different at the p = 0.05 level.

Table 3 (cont'd)

A summary of the environmental data associated with each TWINSPAN vegetation class

Variable	Class	Sample Size	Mean	Standard Error	Min	Max	ANOVA MRT[1]	ANOVA F
nitrate	1	18	1.96	0.30	0.50	6.84	a	6.89
µg/g	2	29	4.55	0.71	0.60	13.80	a	
	3	13	3.13	0.69	0.65	8.30	a	
	4	39	9.97	3.22	1.06	104.00	a	
	5	41	4.04	0.60	0.50	14.75	a	
	6	21	18.52	2.62	1.84	47.50	b	
sand	1	18	86.7	1.2	77.4	95.5	ab	39.868
%	2	29	78.2	2.1	49.3	91.3	ab	
	3	13	79.9	1.9	69.8	94.6	ab	
	4	33	65.8	4.6	8.4	90.4	ab	
	5	39	77.4	1.9	45.0	92.1	a	
	6	21	18.4	6.0	3.1	87.5	ab	
silt	1	18	10.2	1.0	3.3	19.6	a	28.541
%	2	29	15.9	2.0	5.1	38.5	ab	
	3	13	15.3	1.7	3.7	24.1	ab	
	4	33	25.6	4.1	6.6	81.0	b	
	5	39	16.1	1.5	5.4	41.3	ab	
	6	21	58.7	4.7	7.9	84.3	c	
clay	1	18	4.4	1.4	0.8	29.0	a	35.557
%	2	29	5.8	0.5	2.1	12.1	a	
	3	13	4.7	0.3	1.6	6.9	a	
	4	33	8.5	0.9	2.1	25.1	a	
	5	39	6.3	0.6	1.6	25.1	a	
	6	21	22.8	2.0	4.6	34.4	b	
organic	1	18	2.7	0.3	1.2	5.4	a	4.474
matter	2	29	5.4	0.4	1.8	12.0	a	
%	3	13	3.0	0.3	1.9	6.4	a	
	4	39	18.1	3.7	1.6	80.4	b	
	5	41	11.4	2.5	1.8	86.2	ab	
	6	21	13.8	2.5	4.2	55.7	ab	
pH	1	18	5.4	0.2	4.7	7.4	b	30.96
	2	29	5.4	0.1	4.3	7.1	b	
	3	13	5.5	0.1	4.8	6.6	bc	
	4	39	6.1	0.1	4.4	7.6	c	
	5	41	4.7	0.1	3.5	6.6	a	
	6	21	7.3	0.1	5.5	7.7	d	

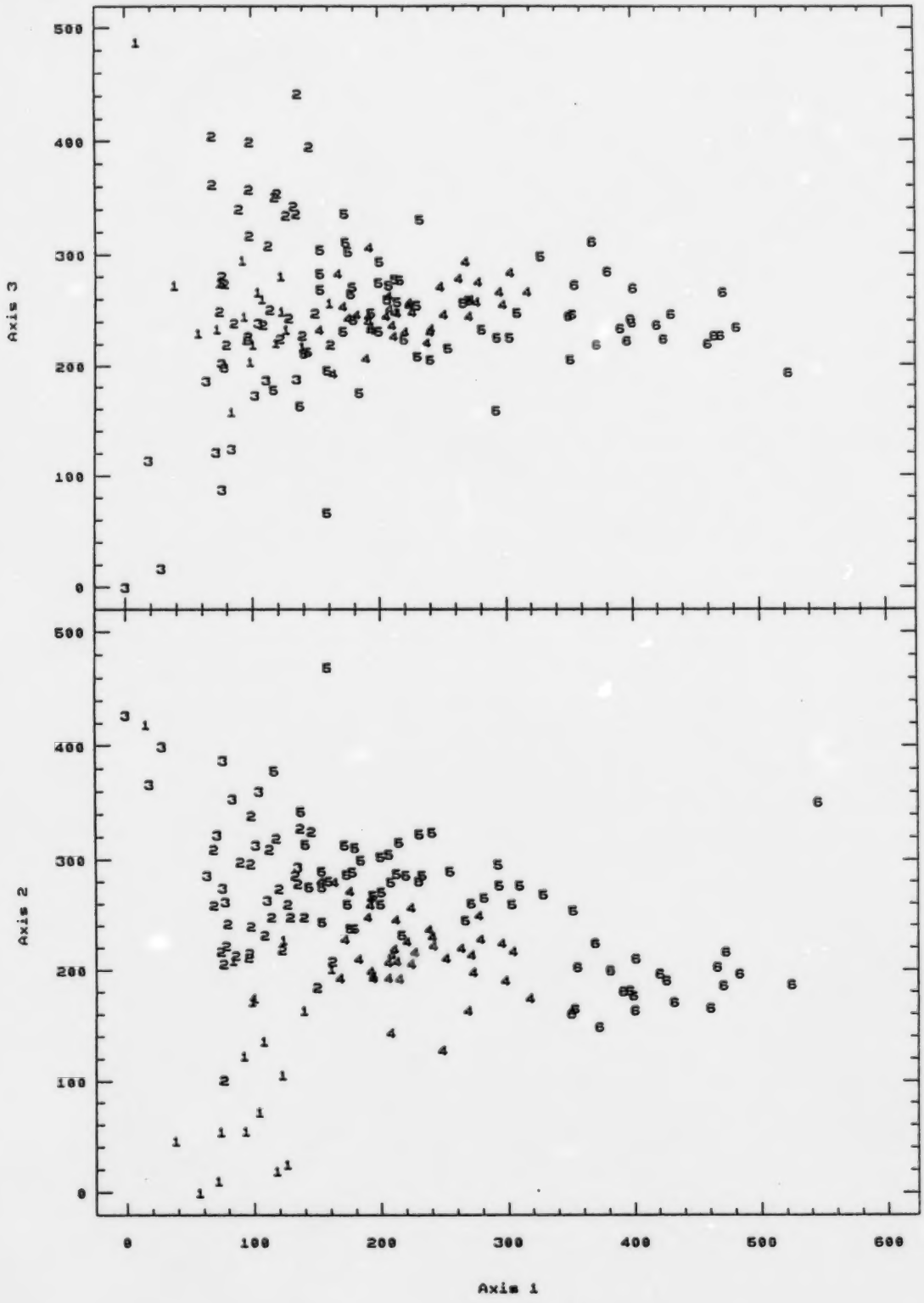

FIGURE 4

THE DCA ORDINATION OF THE 161 RIGHT-OF-WAY QUADRATS. THE UPPER FIGURE IS A PLOT OF AXIS 1 AND 3, WHILE THE LOWER FIGURE IS A PLOT OF AXIS 1 AND 2. NUMBERS INDICATE THE TWINSPLAN CLASSIFICATION OF EACH QUADRAT.

Table 4

Spearman's rank correlations between the environmental variables and quadrat locations determined by the DCA ordination of the right-of-way quadrats

Parameter	DCA Axis			
	1	2	3	4
year (r^2)	.2437	.0417	.0995	.1143
(p)	.0020	.5980	.2082	.1484
distance	-.2920	.5321	.1118	.2708
	.0002	.0000	.1572	.0006
PO_4	-.0716	-.1569	-.0482	-.2746
	.3649	.0472	.5420	.0005
K	-.0634	.0317	-.1499	-.2779
	.4229	.6889	.0579	.0004
Mg	.5426	-.1207	-.0982	-.2660
	.0000	.1269	.2140	.0008
Ca	.5568	-.3293	-.0389	-.3338
	.0000	.0000	.6224	.0000
NO_3	.3889	-.1402	.1922	-.2705
	.0000	.0761	.0151	.0006
om	.6480	-.0598	-.0095	-.1117
	.0000	.4490	.9042	.1577
pH	.3828	-.3732	-.0416	-.4030
	.0000	.0000	.5985	.0000
sand	-.4827	.1627	-.0138	.2687
	.0000	.0449	.8653	.0009
silt	.4219	-.1732	.0139	-.2316
	.0000	.0327	.8636	.0043
clay	.5433	-.1971	-.0417	-.2339
	.0000	.0151	.6069	.0039

The relationships between the derived DCA ordination and the environmental data set can be visualized on the combined weighed-averages ordination (Figure 5). This analysis can be superimposed on the DCA plot (Figure 4), such that each environmental pseudovariable is located near the mean of its distribution in the quadrats. Two distinct variable groups exist on the first axis, demonstrating a large discontinuity in the data. The right side of the plot consists of soils high in organic matter, clay and silt contents, as well as high levels of magnesium, calcium and nitrate. This corresponds to the T835 quadrats and vegetation class 6 of the TWINSPAN analysis, verifying the preliminary indications of the ANOVA that this vegetation class was found on a distinctive soil type (Table 3). The remainder of the environmental variables were clustered in the upper left quadrant. No directional change in the vegetation resulting from the herbicide treatments could be observed, as indicated by the apparently random location of the treatment year pseudovariables. The longest gradient on the second axis was related to distance.

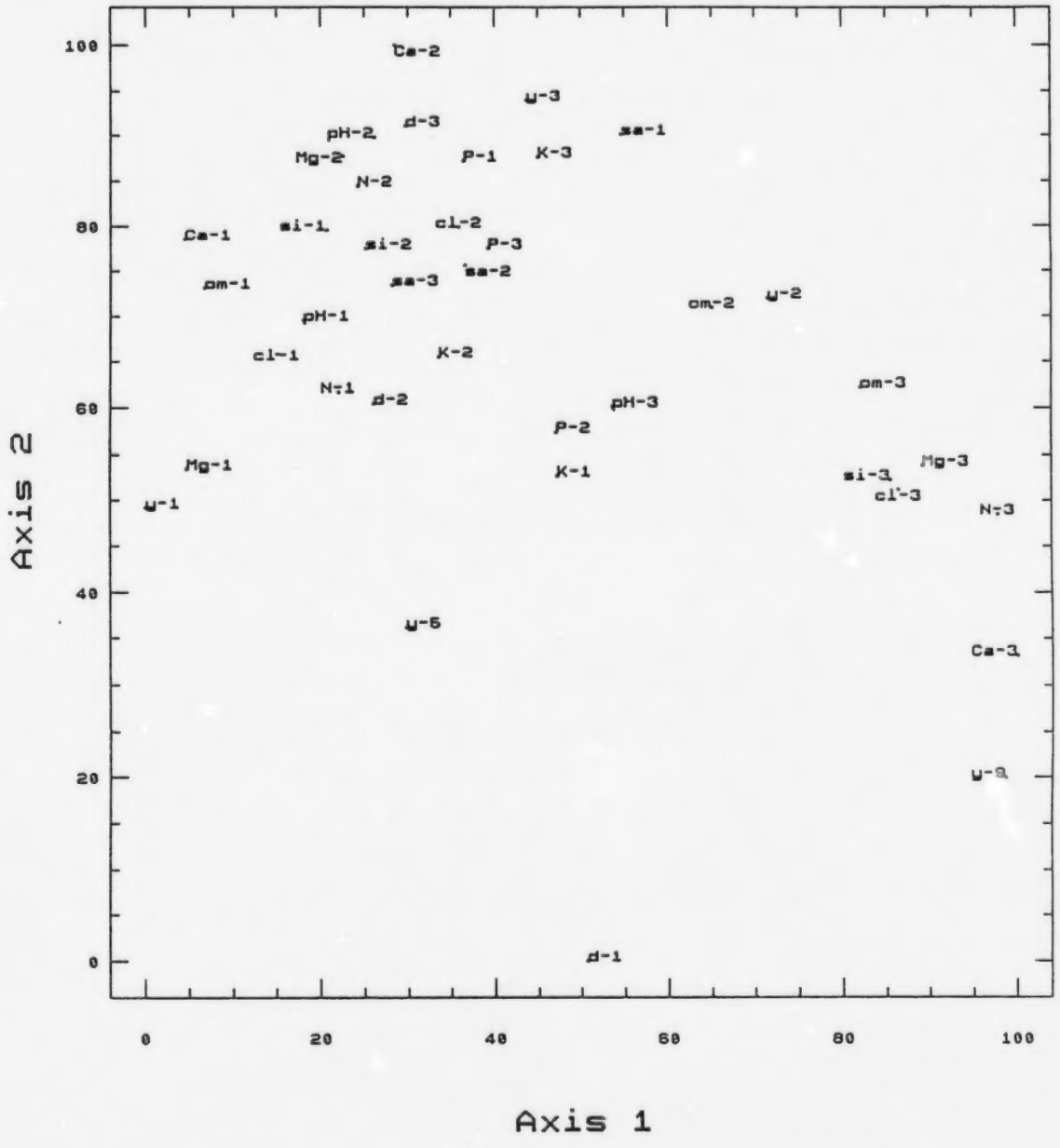

FIGURE 5

THE WEIGHTED AVERAGES ORDINATION OF THE ENVIRONMENTAL VARIABLES. THIS PLOT CAN BE SUPERIMPOSED ON THE QUADRAT ORDINATION (LOWER PLOT OF FIGURE 4) TO DISPLAY THE ENVIRONMENTAL GRADIENTS ASSOCIATED WITH THE FIRST TWO ORDINATION AXES. THE VARIABLES ARE Y = YEAR, D = DISTANCE, Ca = CALCIUM, Mg = MAGNESIUM, N = NITRATE, K = POTASSIUM, P = PHOSPHORUS, OM = ORGANIC MATTER, SA = SAND, SI = SILT, CL = CLAY, pH. -1, -2, -3 INDICATE LOW, MEDIUM AND HIGH PSEUDOVARIABLES DEFINED BY TABLE II.

The possibility that the large differences in soil type between TWINSPAN class 6 and the other classes is masking more subtle gradients in the data cannot be overlooked. Therefore, the T835 quadrats were removed and the remainder of the data set was ordinated (Figure 6). This re-analysis produced an insignificant reversal of axis 1, and a slight change in the location of the class 1 vegetation. However, several differences were observed in the correlation analysis of the ordination (Table 5). The soil texture parameters were no longer significantly related to any axis. Axis 1 was found to be correlated to phosphate, and negatively correlated to the number of years since treatments. (The correlations for potassium, magnesium and organic matter were not apparent from scattergrams of the data). The second DCA axis was not correlated to any of the measured parameters. Axis 3 showed correlations with the distance north and soil pH.

The primary interest in this project was to determine the successional pattern of the vegetation following herbicide treatment. The ANOVA analysis (Table 3) indicated that the distribution of the vegetation classes was affected by the year of treatment variable, although the F statistic was small. This is broadly reflected in the first two levels of the TWINSPAN division (Figure 3). Vegetation classes 1,2 and 3 were found more often on the recently treated rights-of-ways, while the older rights-of-ways had vegetation of classes 4 and 5. However, this is more likely artifactual, resulting from the tendency of the quadrats at each site to clump together. Figures 7 and 8 show an overlay of the treatment year on the ordination plots of the right-of-way data and right-of-way minus T835 quadrats. There is no clustering of treatment years beyond that associated with the grouping of the quadrats within each site, thus there is not a well defined pattern of succession in the DCA analysis. Interpretation of these results was also confounded by the herbicide application method, selective spot treatments of locations occupied by incompatible species. Thus an unknown portion of the quadrats at each site were not treated in the year specified (as they contained no incompatible species). A larger degree of site replication will be required to determine if such year-of-treatment effects are real.

It is possible that the vegetation composition is more affected by the treatment used rather than the time interval following the treatment. Figure 9 shows the location of each transect on the DCA ordination and the treatments used. The sites treated with Krenite (fosamine-ammonium) were scattered through the left side the plot, while those treated with 2,4 D/DP and Tordon (picloram and 2,4 D) were clustered in a narrow band in the middle of axis 2. This is a preliminary indication that 2,4 D/DP and picloram has a different effect on the vegetation as a whole that Krenite.

3.2 Effects on community structure

A summary of the species richness, diversity and evenness of the 6 right-of-way communities and the adjacent woodlots is given in Table 6. (Richness is the number of species present, diversity represents a combination of species richness and relative abundance, while evenness is related to the relative distribution of species abundances in the community.) Vegetation class 4 was the most diverse of the communities, with a richness of 22.77 ± 1.11 species per quadrat(mean$\pm$SE), and a diversity of 2.67. The simplest communities were found in the woodlands, with 9.58 ± 2.52 species per quadrat and a diversity of 1.72 ± 0.81. All vegetation types had similar species evenness, ranging from 0.8 to 0.87.

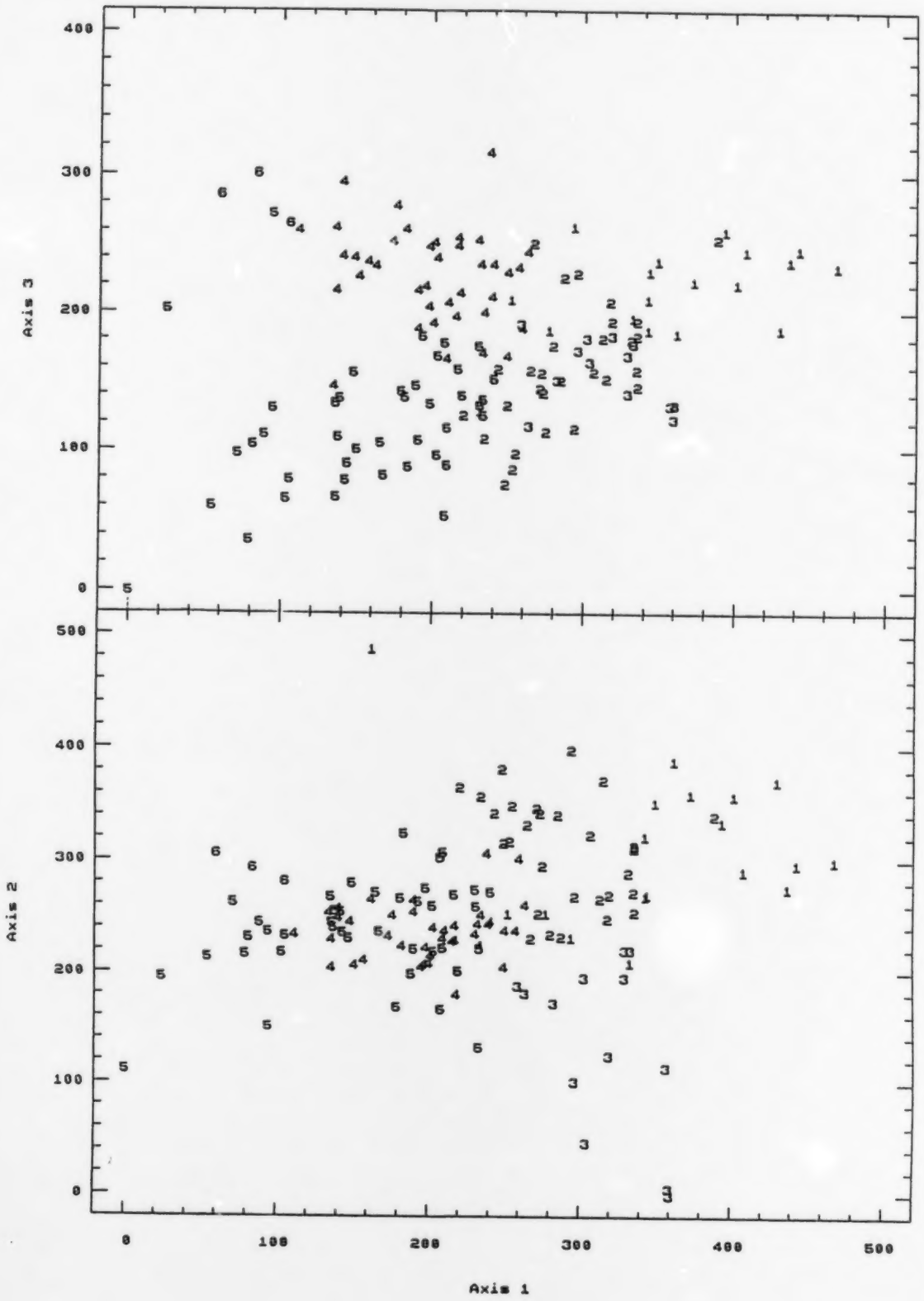

FIGURE 6

THE DCA ORDINATION OF THE RIGHT-OF-WAY QUADRATS FOLLOWING THE REMOVAL OF THE T835 QUADRATS. THE UPPER FIGURE IS A PLOT OF AXIS 1 AND 3, WHILE THE LOWER FIGURE IS A PLOT OF AXIS 1 AND 2. NUMBERS INDICATE THE TWINSPAN CLASSIFICATION OF EACH QUADRAT.

Table 5

Spearman's rank correlations between the environmental variables and quadrat location determined by the DCA ordination following the removal of the T835 quadrats

Parameter	DCA Axis 1	2	3	4
year (r^2)	-.3932	-.0007	-.0349	.0031
(p)	.0000	.9930	.6774	.9708
distance	-.2004	.0433	-.6354	.0946
	.0170	.6062	.0000	.2594
PO_4	.3840	.1161	.0828	.3735
	.0000	.1667	.3238	.0000
K	.3070	-.0843	-.1899	.2723
	.0003	.3151	.0236	.0012
Mg	-.3243	-.2379	.0517	.1650
	.0001	.0046	.5380	.0493
Ca	-.2406	-.1063	.3108	.2532
	.0041	.2052	.0002	.0025
NO_3	-.1525	.1033	.0036	.2928
	.0692	.2183	.9658	.0005
pH	.0372	-.0021	.3628	.3922
	.6578	.9797	.0000	.0000
om	-.5583	-.2016	-.0393	-.0872
	.0000	.0163	.6397	.2990
sand	.1733	.0979	.0156	.0078
	.0448	.2569	.8568	.9276
silt	-.1133	-.0582	-.0355	-.0907
	.1897	.5005	.6810	.2935
clay	-.2502	-.1604	.0467	.0064
	.0038	.0633	.5886	.9406

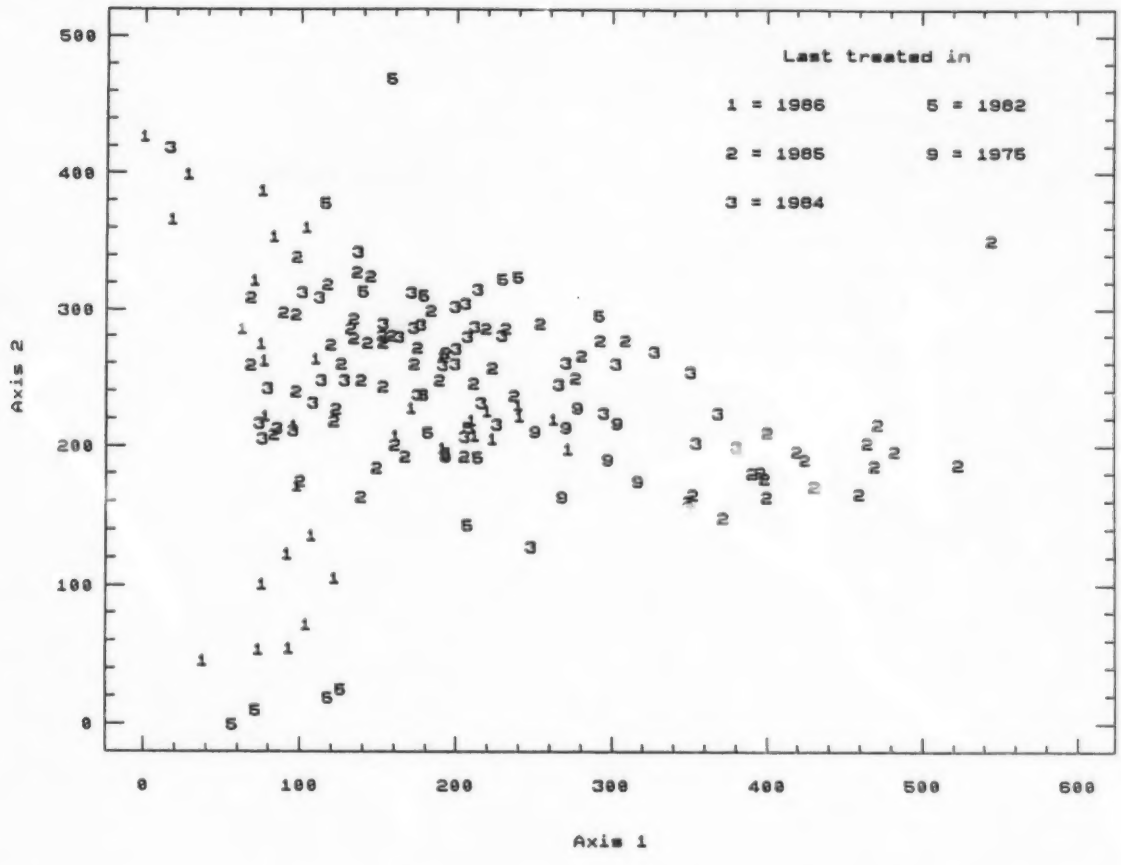

FIGURE 7

THE FIRST TWO AXES OF THE DCA ORDINATION OF THE 161 RIGHT-OF-WAY QUADRATS (LOWER PLOT OF FIGURE 4) SHOWING THE TIME ELAPSED SINCE THEIR LAST HERBICIDE TREATMENTS.

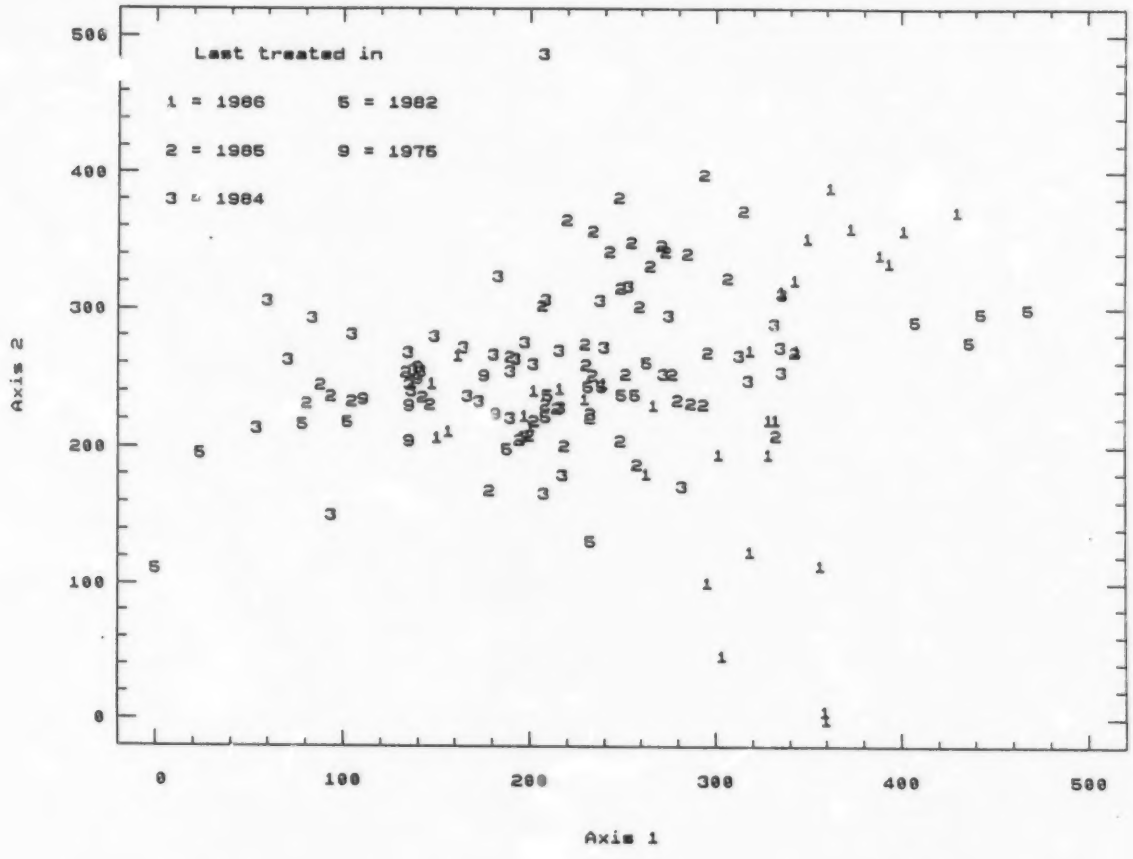

FIGURE 8

THE FIRST TWO AXES OF THE DCA ORDINATION OF THE RIGHT-OF-WAY QUADRATS FOLLOWING REMOVAL OF THE T835 QUADRATS (LOWER PLOT OF FIGURE 6) SHOWING THE TIME ELAPSED SINCE THEIR LAST HERBICIDE TREATMENTS.

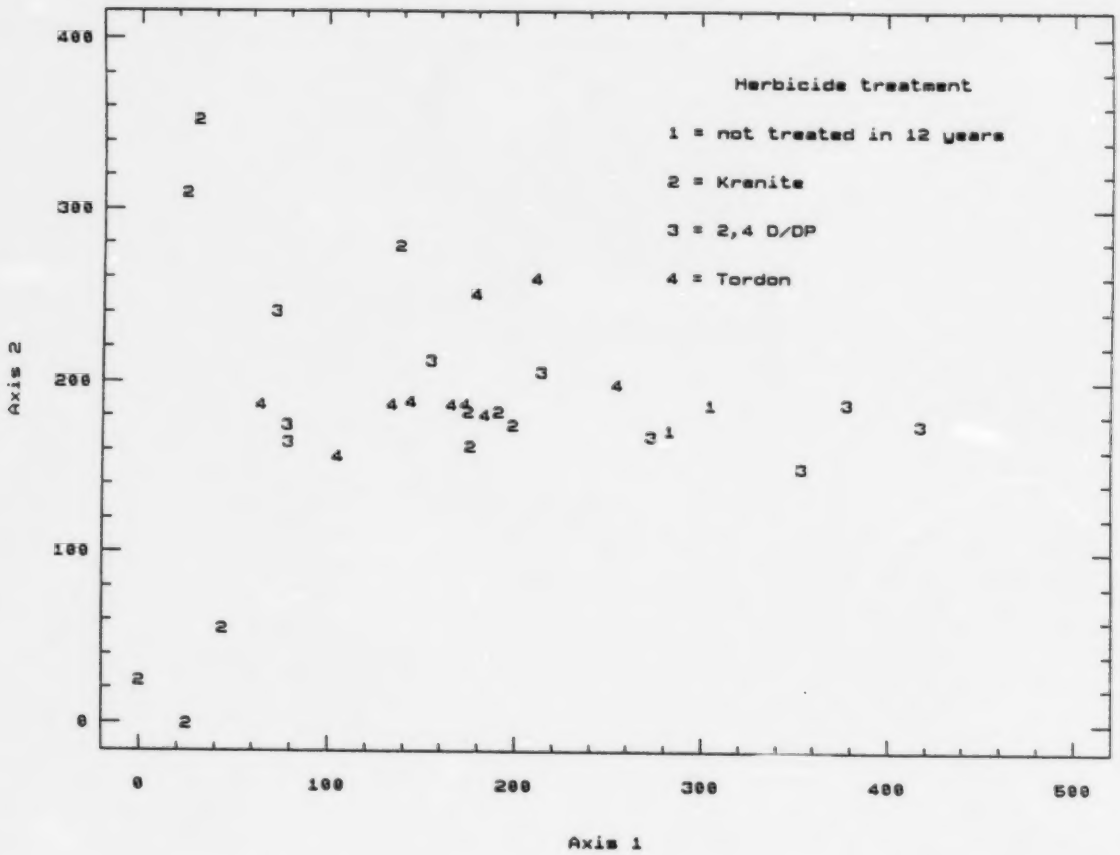

FIGURE 9

THE FIRST TWO AXES OF A DCA ORDINATION OF EACH TRANSECT, SHOWING THE HERBICIDE LAST USED.

Table 6

A summary of the species structure of the six different right-of-way communities and the adjacent woodlots

Parameter	Class	Sample Size	Mean	Standard Error
Species Richness	1	18	15.17	1.54
	2	29	11.41	0.88
	3	13	11.08	0.84
	4	39	22.77	1.11
	5	41	13.46	0.98
	6	21	11.71	0.90
	woods	62	9.58	2.52
Diversity	1	18	2.25	0.11
	2	29	1.97	0.07
	3	13	1.92	0.08
	4	39	2.67	0.05
	5	41	2.04	0.10
	6	20	2.05	0.07
	woods	59	1.72	0.81
Evenness	1	18	0.856	0.012
	2	29	0.839	0.009
	3	13	0.806	0.012
	4	39	0.869	0.006
	5	41	0.838	0.014
	6	20	0.827	0.013
	woods	59	0.812	0.321

The clearing of the right-of-way and subsequent herbicide treatments has a large effect on the species make-up of the community (Figure 2), and some changes can be observed in the community structure. Lines undergoing normal operational treatments (ie. treated within the past 5 years) had an intermediate species richness (14 to 17 species per quadrat) and diversity (2.1), while the idle line (last treated in 1975) had the highest richness (21.71 ± 1.34) and diversity (2.68 ± 0.077) (Table 7). These parameters then decreased for the woodlots (Table 6).

The type of herbicide used seem to have differential effects on the community structure. The lines treated with Krenite tended to have more species (16.01 ± 0.31 per quadrat) than those treated with 2,4 D/DP (13.91 ± 0.72) or Tordon (14.63 ± 0.96) (Table 8). In contrast, 2,4 D/DP and Krenite produced communities of similar diversity (2.20 ± 0.069 and 2.19 ± 0.091) while Tordon generated a less diverse plant cover (2.14 ± 0.06).

3.3 The relationship between trees and vegetation

Fifty of the 161 quadrats on the right-of-way contained at least 1 stem of an incompatible tree species (*Acer negundo*, *A. rubrum*, *A. saccharum*, *Aesculus hippocastanum*, *Alnus incana*, *Betula papyrifera*, *Crataegus* sp. *Fraxinus americana*, *Malus* sp., *Populus balsamifera*, *P. deltoides*, *Prunus serotina*, *Ulmus* sp., *Fagus grandifolia* and *Tilia americana*). This corresponds to a frequency of 31%, with a minimum estimated density of 1 stem m^{-2}. Chi-square analysis

indicated that no significant relationship exists between the occurrence of these trees and the vegetation class (Table 9, $X^2 = 5.552$, $p = 0.35$) or the number of years since the lines were last treated (Table 10, $X^2 = 4.509$, $p = 0.341$). Analysis of species relationships indicated that 17 species had positive associations with the incompatible trees (*Aster schreberi, Dryopteris cristata, Erigeron annuus, Geum spp., Maianthemum canadensis, Prunus pensylvanica, Pyrola rotundifolia, Ribes hirtellum, Sambucus canadensis, Smilacina racemosa, Smilax herbacea, Solanum dulcamara, Taraxacum officinale, Thalictrum dioicum, Tiarella cordifolia, Veronica officinalis* and *Viola* spp.) while *Potentilla recta* was the only species with a distribution which demonstrated a significant negative association with the trees.

Table 7

A summary of the changes in community structure with time following herbicide treatment of the right-of-way

Parameter	Treatment Year	Sample Size	Mean	Standard Error
Species Richness	1986	33	16.61	1.77
	1985	63	14.44	0.79
	1984	41	13.92	0.86
	1982	17	14.88	1.82
	1975	7	21.71	1.34
Diversity	1986	33	2.24	0.098
	1985	62	2.18	0.057
	1984	41	2.14	0.075
	1982	17	2.10	0.189
	1975	7	2.68	0.077
Evenness	1986	33	0.840	0.010
	1985	62	0.843	0.006
	1984	41	0.841	0.008
	1982	17	0.845	0.033
	1975	7	0.873	0.009

Table 8

A summary of the effects of various types of herbicides on the community structure of the right-of-way

Parameter	Herbicide	Sample Size	Mean	Standard Error
Richness	Krenite	50	16.02	1.31
	2,4 D/DP	48	14.63	0.96
	Tordon	56	13.91	0.72
Diversity	Krenite	50	2.19	0.091
	2,4 D/DP	47	2.20	0.069
	Tordon	56	2.14	0.060
Evenness	Krenite	50	0.842	0.013
	2,4 D/DP	47	0.844	0.007
	Tordon	56	0.841	0.007

Table 9

Chi-square tests of the relationship between the TWINSPAN vegetation classes and the presence of incompatible trees on the right-of-way

Vegetation Class	Observed Frequence	Expected Frequency	Chi-square
1	1	6.5	3.759
2	11	9.0	0.449
3	4	4.0	0.000
4	16	12.1	1.265
5	12	12.7	0.039
6	6	6.5	0.039

Chi-square = 5.552 with 5 d.f, p = 0.35

Table 10

Chi-square tests of the relationship between the presence of incompatible trees and the number of years since treatment of the right-of-way

Last Year Treated	Observed Frequency	Expected Frequency	Chi-square
1986	10	10.2	0.004
1985	25	19.5	1.551
1984	10	12.7	0.574
1982	2	5.3	2.063
1975	3	2.2	0.317

Chi-square = 4.509 with 4 d.f., p = 0.341

4.0 DISCUSSION

The most striking feature of the right-of-way vegetation observed in this study is its high variability. Although the sites were initially chosen from a preliminary survey to be as uniform as possible, there was still considerable variation between locations. This can cause several problems for the interpretation of results and in the design of future studies. Extensive replication of sites is required to distinguish between treatment effects and the initial differences in vegetation between the sites. Several studies (Niering and Goodwin 1974, Jotcham 1985, Dreyer and Niering 1986) also indicated that the right-of-way vegetation can be quite variable, even on a local scale. However, a study of a 895 km transmission corridor in Manitoba (MacLellan and Stewart 1986), observed similar vegetation along the length of the line, in contrast to the three distinct communities in the adjacent, undisturbed vegetation. MacLellan and Stewart hypothesized that the transmission corridor acted as a "funnel" for the spread of propagules along the right-of-way, allowing the establishment of plants in communities outside their natural range. Repeated disturbances by right-of-way maintenance prevented development of communities which followed the natural vegetation zones, and encouraged formation of an undifferentiated plant cover. Unfortunately for vegetation managers, this situation appears to represent an exception and they are faced with the task of developing a control program for rights-of-way with many different and continually changing plant communities.

Six different communities could be identified from this study. Four of these appeared at several sites, while the other two were primarily located at only one site (Figure 3). The large differences in soil characteristics observed at the T835 quadrats (Table 3) most likely account for the uniqueness of the class 6 vegetation found at this location (Figure 3, 4), and is responsible for the high correlations observed between DCA axis 1 and the soil and nutrient variables (Table 4, Figure 5). Removal of this site from the analysis left phosphate content as

the only measured soil or nutrient parameter associated with the ordination axes (Table 5). Soil moisture and drainage, two variables not measured in this study, most likely represent important factors related to the species distribution. Similarly, the correlation between the north-south distribution of the sites and DCA axis 2 (Figure 4, Table 4) suggests slight climatic differences over the 70 km which separate the extreme sites. This is very surprising, considering MacLellan and Stewart (1986) did not observe a north-south trend over a distance of 700 km.

Treatment effects, beyond that obviously associated with the removal of tall trees, do not seem to play a well defined role in the vegetation of an operational right-of-way. No successional or cyclic trends were observed as a response to the herbicide treatments (Figure 7,8), and insignificant changes in species richness, diversity or evenness occurred under the normal treatment cycle of 4-5 years (Table 7). The rights-of-way in this study contained 6 communities which have developed in response to a recurring disturbance. Although the distribution of these communities may be affected by the year of treatment (Table 3), the data is far from being conclusive (Figure 7).

The vegetational development of a newly established right-of-way cut through a woodlot would consist of an initial re-invasion of the species present in the woodlot (Bramble and Byrnes 1983, Thibodeau and Nickerson 1986, Brown 1987). This study gives no indication of the 'classic' successionary sequence involving a directional change from a pioneer through several intermediates to the climax stage, where each stage prepares the way for subsequent stages. Instead, this rapid re-invasion of the woodland (climax) species led Egler (1954) to propose the Initial Floristic Composition (IFC) theory of vegetation development, which has since been modified by Connell and Slatyer (1977) into the tolerance and inhibition models.

In the IFC theory, any species with representatives in the seed or propagule bank at the time of line clearing operations can invade the site (in contrast to a select few pioneer species in the classic model). Growth of this community, with its associated environmental changes, results in the competitive replacement of less tolerant by more tolerant plants (the tolerance model), eventually leading to a "climax" community formed by the most tolerant species available. Alternatively, no two plants can occupy the same space, so once an individual has become established it will inhibit the invasion of subsequent individuals until the colonizer dies and releases its space and resources. This space is then colonized by any propagule able to establish and grow there, which in turn inhibits the establishment of other individuals (the inhibition model). If the replacer is a different species, then a gradual change in the community will be observed. If the individual is generally replaced by another member of the same species, then no net change will occur and a stable community may develop.

Both the tolerance and inhibition models are applicable to an operational right-of-way. The proclimax right-of-way community discussed by Bramble and Byrnes (1983) appears to follow the tolerance model. The repeated herbicide applications impose a stress and the vegetation is dominated by herbicide tolerant species which reproduce by rhizomes, stump sprouts and root suckers. However, many researchers have emphasized the need to develop a selective herbicide application policy in which only the tall growing, incompatible trees are removed from the right-of-way (Niering and Egler 1955, Egler 1958, Niering and Goodwin 1974, Bramble and Byrnes 1976), thus encouraging the development of a compatible vegetation cover which reduces the establishment of incompatible trees through an inhibition model.

There are a few examples of plant communities which have resisted tree invasion for several years. A thicket of *Viburnum lentago* growing in an abandoned Connecticut pasture remained stable for 45 years (Niering and Egler 1955, Niering and Goodwin 1974). In New York State, a one-half mile stretch of a 40 mile long firebreak developed a community dominated by *Comptonia peregrina, Dennstaedtia punctilobula, Dryopteris noveboracensis, Gaylussacia baccata,*

Kalmia angustifolia and *Vaccinium angustifolium* which has resisted tree establishment for 25 years (Pound and Egler 1953). Niering and Goodwin (1974) observed communities of *Gaylussacia baccata*, *Vaccinium vacillans* and *Smilax* sp., as well as those dominated by *Andropogon scoparius* which remained stable for 15 years on a Connecticut right-of-way. In contrast, large clumps of these species (*Gaylussacia baccata, Dennstaedtia punctilobula, Comptonia peregrina* and *Rubus alleghaniensis*) are reported to be easily invaded by tree species in a Pennsylvania right-of-way study (Bramble and Byrnes 1976). Species found to be resistant to tree invasion in the Bramble and Byrnes study were *Solidago rugosa, Festuca elatior, Quercus ilicifolia*, and *Lysimachia quadrifolia* when growing in individual patches, and a community dominated by *Vaccinium angustifolium*, *Quercus ilicifolia*, and *Solidago graminifolia*. However, a community dominated by a two-species mixture of *Vaccinium angustifolium* and *Quercus ilicifolia* was easily invaded, while the the most common community (*Pteridium aquilinum, Carex pensylvanica, Lysimachia quadrifolia* and *Vaccinium)* was also heavily invaded by tree seedlings.

It appears that the occurrence of plant communities with the ability to inhibit tree invasion or growth are highly fortuitous, and even with extensive selective maintenance, their creation is a highly elusive goal (Jotcham 1985). The initial suggestion of Egler (1958) that low growing shrubs are beneficial to rights-of-way maintenance has not been observed in subsequent studies (Dreyer and Niering 1986). It cannot be generalized as to which type of plant (grass, forb or shrub) may form a stable cover, as there are desirable and undesirable representatives of each life form (Bramble and Byrnes 1976). With the exception of the few communities mentioned above, all of the rights-of-way would most likely revert to a tree cover if left unmanaged for several years due to the continuous pressure exerted on the area from the surrounding woodlands. This process might be delayed by dense plant growth encouraged by a selective herbicide control policy (Bramble and Byrnes 1983), but it cannot be prevented entirely. Alternatively, the natural vegetation could be replaced by the planting of a cover (smother) crop selected for its ability to inhibit incompatible trees. The difficult task which confronts the vegetation control manager is to develop a management policy which produces an optimum, long term balance of cost, environmental acceptability and vegetational stability using the available methods of chemical, mechanical and biological controls.

None of the 6 right-of-way communities identified in this study differed in the frequency of occurrence of tree species (Table 9). As the frequency of trees on the right-of-way does not appear to change following herbicide treatments (Table 10, and Bramble *et al.* 1984) it appears that either the treatments are ineffective at reducing total tree frequency, or that these sites are rapidly colonized by tree seedlings following treatment. However, this does not mean that each community is equally suitable (or unsuitable) for creating a stable cover, as the seed pressures exerted by the surrounding woodlots will be different at each site. Thus it cannot be determined from this study which, if any, of these communities may form a desirable cover. A study which quantifies the germination of a known number of tree seeds placed on the sites, or measures the relative competitive ability of each community on the growth of tree seedlings planted in the communities, is necessary to better define the suitability of the communities as a right-of-way cover. A project is currently underway to examine the effects of these communities on the survival and growth of two-year old *Fraxinus pensylvanica* seedlings.

5.0 CONCLUSIONS

1. Six vegetation communities were identified by the classification analysis of the right-of-way quadrats. The distribution of these communities was affected by soil texture Mg, Ca and organic matter. A north-south gradient and the time elapsed since herbicide treatment may play a secondary role in the distribution of these communities. A more intensive study will be required to investigate this possibility.

2. The frequency of incompatible trees observed in this study is 31%, corresponding to an estimated density of 1 stem m^{-2}. Their distribution was not affected by the vegetation type or time elapsed since herbicide treatment.

3. A new study has commenced to investigate the competative ability of the six vegetation communities, using *Fraxinus pensylvanica* as the target tree species.

ACKNOWLEDGMENTS

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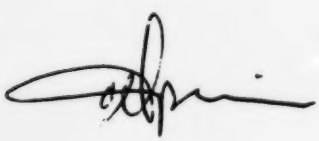

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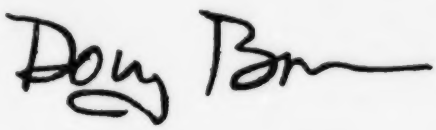

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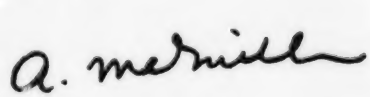

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Appendix A

A List of the Species included in this Study

Common name	Scientific name
balsam fir	*Abies balsamea*
velvet leaf	*Abutilon theophrasti*
Manitoba maple	*Acer negundo*
red maple	*Acer rubrum*
sugar maple	*Acer saccharum*
yarrow	*Achillea millefolium*
white baneberry	*Actaea pachypoda*
maidenhair fern	*Adiantum pedantum*
horse chestnut	*Aesculus hippocastanum*
agrimony	*Agrimonia sp.*
couch-grass	*Agropyron repens*
bentgrass	*Agrostis sp.*
speckled alder	*Alnus incana*
common ragweed	*Ambrosia artemisiaefolia*
smooth serviceberry	*Amelanchier laevis*
serviceberry	*Amelanchier sanguinea*
pearly everlasting	*Anaphalis margaritacea*
Canada anemone	*Anemone canadensis*
long-headed thimbleweed	*Anemone cylindrica*
thimbleweed	*Anemone riparia*
anemone	*Anemone sp.*
Alexanders	*Angelica atropurpurea*
spreading dogbane	*Apocynum androsaemifolium*
sickelpod	*Arabis canadensis*
smooth rockcress	*Arabis laevigata*
purple milkweed	*Asclepias purpurascens*
common milkweed	*Asclepias syriaca*
Aster	*Aster a*
Aster b	*Aster b*
Loweries Aster	*Aster lowrieanus*
Schreber's aster	*Aster schreberi*
Aster sp.	*Aster sp.*
flat-topped-white aster	*Aster umbellatus*
lady fern	*Athyrium filix-femina*
oranche	*Atriplex patula*
wintercress	*Barbarea vulgaris*
white birch	*Betula papyrifera*
false nettle	*Boehmeria cylindrica*
northern moonwort	*Botrychium boreale*
lanceolate moonwort	*Botrychium lanceolatum*
leathery moonwort	*Botrychium multifidum*
water arum	*Calla palustris*
furry seeded	*Carex a*
	Carex b
starved wood sedge	*Carex depauperata*
star sedge	*Carex echinata*

	Carex flava
	Carex intumescens
yellow sedge	*Carex lurida*
hop sedge	*Carex pseudo-cyperus*
	Carex stipata
thin-spiked wood sedge	*Carex strigosa*
	Carex sylvaticu
American fox sedge	*Carex vulpinoidea*
New Jersey Tea	*Ceanothus americanus*
bittersweet	*Celastrus scandens*
buttonbush	*Cephalanthus occidentalis*
mouse-ear chickweed	*Cerastium vulgatum*
lamb's quarters	*Chenopodium album*
ox-eye daisy	*Chrysanthemum leucanthemum*
enchanter's nightshade	*Circaea quadrisulcata*
Canada thistle	*Cirsium arvense*
	Cladonia coccifera
	Cladonia mittis
reindeer lichen	*Cladonia rangiferina*
virgins bower	*Clematis virginiana*
clinton	*Clintonia borealis*
field bindweed	*Convolvulus arvensis*
upright bindweed	*Convolvulus spithamaeus*
horseweed	*Conyza canadensis*
alternate-lvd dogwood	*Cornus alternifolia*
gray dogwood	*Cornus racemosa*
round leaved dogwood	*Cornus rugosa*
red osier dogwood	*Cornus stolonifera*
beaked hazelnut	*Corylus cornuta*
hawthorn	*Crataegus flabellata*
downy hawthorn	*Crataegus mollis*
wild carrot	*Daucus carota*
showy tick-trefoil	*Desmodium canadense*
pointed-lvd. tick-trefoil	*Desmodium glutinosum*
bush honeysuckle	*Diervilla lonicera*
crested bucklerfern	*Dryopteris cristata*
wild cucumber	*Echinocystis lobata*
fireweed	*Epilobium angustifolium*
northern willow herb	*Epilobium glandulosum*
helleborine	*Epipactis helleborine*
field horsetail	*Equisetum arvense*
scouring rush	*Equisetum hyemale*
marsh horsetail	*Equisetum palustre*
dwarf scouring rush	*Equisetum scirpoides*
wood horsetail	*Equisetum sylvaticum*
daisy fleabane	*Erigeron annuus*
Canada fleabane	*Erigeron canadensis*
Philadelphia fleabane	*Erigeron philadelphicus*
burning bush	*Euonymus atropurpureus*
spotted Joe-Pye weed	*Eupatorium maculatum*
boneset	*Eupatorium perfoliatum*
buckwheat	*Fagopyrum sagittatum*
American beech	*Fagus grandifolia*

fern A	*Fern A*
	Fern B
meadow fescue	*Festuca elatior*
	Festuca sp.
strawberry	*Fragaria virginiana*
white ash	*Fraxinus americana*
red ash	*Fraxinus pensylvanica*
northern bedstraw	*Galium boreale*
sweet-scented bedstraw	*Galium triflorum*
wintergreen	*Gaultheria procumbens*
	Geranium maculatum
herb-Robert	*Geranium robertianum*
	Geranium sp.
yellow avens	*Geum aleppicum*
white avens	*Geum canadense*
avens	*Geum sp.*
rough avens	*Geum virginianum*
oak fern	*Gymnocarpium dryopteris*
sharp-lobed hepatica	*Hepatica acutiloba*
orange hawkweed	*Hieracium aurantiacum*
hairy hawkweed	*Hieracium gronovii*
mouse eared hawkweed	*Hieracium pilosell*
king devil	*Hieracium pratense*
non flowering	*Hieracium sp.*
virginia waterleaf	*Hydrophyllum virginianum*
common St. Johns-wort	*Hypericum perforatum*
spotted St. Johns-wort	*Hypericum punctatum*
marsh St. Johns-wort	*Hypericum virginicum*
bottle brush grass	*Hystrix patula*
black alder	*Ilex verticillata*
sharp rush	*Juncus acutus*
grass-leaved rush	*Juncus planifolius*
slender rush	*Juncus tenuis*
pyramidal hairgrass	*Koeleria pyramidata*
wild lettuce	*Lactuca canadensis*
hairy lettuce	*Lactuca hirsuta*
prickly lettuce	*Lactuca scariola*
wood nettle	*Laportea canadensis*
duckweed	*Lemna minor*
field peppergrass	*Lepidium campestre*
indian tobacco	*Lobelia inflata*
birdsfoot trefoil	*Lotus corniculatus*
ground cedar	*Lycopodium obscurum*
cut-leaved bugleweed	*Lycopus americanus*
bugleweed	*Lycopus virginicus*
fringed loosestrife	*Lysimachia ciliata*
wild lily-of-the-valley	*Maianthemum canadensepu*
common apple	*Malus pumila*
apple	*Malus sp.*
black medick	*Medicago lupulina*
white sweet clover	*Melilotus alba*
wild mint	*Mentha arvensis*
square-stemmed monkeyflower	*Mimulus ringens*

	Mint
partridge-berry	*Mitchella repens*
wild bergamont	*Monarda fistulosa*
catnip	*Nepeta cataria*
evening primrose	*Oenothera biennis*
sensitive fern	*Onoclea sensibilis*
adder's tongue	*Ophioglossium vulgatum*
Royal fern	*Osmunda regalis*
hop hornbeam	*Ostrya virginiana*
yellow wood sorrel	*Oxalis europaea*
deer-tongued grass	*Panicum clandestinum*
virginia creeper	*Parthenocissus sp.*
wild bean	*Phaseolus polystachios*
timothy grass	*Phleum pratense*
ground cherry	*Physalis heterophylla*
Jack pine	*Pinus banksiana*
scotch or red	*Pinus sp.*
white pine	*Pinus strobus*
English plantain	*Plantago lanceolata*
common plantain	*Plantago major*
	Poa A
	Poa B
	Poa C
broad-leaved meadow-grass	*Poa chaixii*
Canada bluegrass	*Poa compressa*
Kentucky bluegrass	*Poa pratensis*
May apple	*Podophyllum peltatum*
Solomon's seal	*Polygonatum pubescens*
prostrate knotweed	*Polygonum aviculare*
Christmas fern	*Polystichum acrostichoides*
balsam poplar	*Populus balsamifera*
cottonwood	*Populus deltoides*
dwarf cinquefoil	*Potentilla canadensis*
rough cinquefoil	*Potentilla norvegica*
rough-fruited cinquefoil	*Potentilla recta*
smooth white lettuce	*Prenanthes racemosa*
selfheal	*Prunella vulgaris*
pin cherry	*Prunus pensylvanica*
black cherry	*Prunus serotina*
choke cherry	*Prunus virginiana*
bracken	*Pteridium aquilinum*
shinleaf	*Pyrola elliptica*
round leaved pyrola	*Pyrola rotundifolia*
red oak	*Quercus borealis*
common buttercup	*Ranunculus acris*
white water buttercup	*Ranunculus longirostris*
swamp buttercup	*Ranunculus septentrionalis*
alder-leafed buckthorn	*Rhamnus alnifolia*
common buckthorn	*Rhamnus cathartica*
glossy buckthorn	*Rhamnus frangula*
poison ivy	*Rhus radicans*
staghorn sumac	*Rhus typhina*
wild black current	*Ribes americanum*

wild gooseberry	*Ribes hirtellum*
common blackberry	*Rubus allegheniensis*
smooth blackberry	*Rubus canadensis*
swamp dewberry	*Rubus hispidus*
red raspberry	*Rubus idaeus*
black raspberry	*Rubus occidentalis*
dwarf raspberry	*Rubus pubescens*
sheep sorrel	*Rumex acetosella*
yellow dock	*Rumex crispus*
white willow	*Salix alba*
long-beaked willow	*Salix bebbiana*
blue-leaved willow	*Salix myricoides*
slender willow	*Salix petiolaris*
	Salix sp.
common elderberry	*Sambucus canadensis*
red-fruited elderberry	*Sambucus pubens*
elderberry	*Sambucus sp.*
bloodroot	*Sanguinaria canadensis*
black snakeroot	*Sanicula marylandica*
basil	*Satureja vulgaris*
wool grass	*Scirpus cyperinus*
hairy skullcap	*Scutellaria elliptica*
common skullcap	*Scutellaria epilobiifolia*
downy skullcap	*Scutellaria incana*
maddog skullcap	*Scutellaria lateriflora*
rye grass	*Secale cereale*
bladder campion	*Silene cucubalus*
false Solomon's seal	*Smilacina racemosa*
starry false S S	*Smilacina stellata*
carrion-flower	*Smilax herbacea*
nightshade	*Solanum dulcamara*
	Solidago A
	Solidago B
Canada goldenrod	*Solidago canadensis*
late goldenrod	*Solidago gigantea*
lance-leaved goldenrod	*Solidago graminifolia*
early goldenrod	*Solidago juncea*
gray goldenrod	*Solidago nemoralis*
Ohio goldenrod	*Solidago ohioensis*
rough-stemmed goldenrod	*Solidago rugosa*
	Solidago sp.
field sow thistle	*Sonchus arvensis*
spiny sow thistle	*Sonchus asper*
narrow-lf meadowsweet	*Spiraea alba*
lessor stitchwort	*Stellaria graminea*
long-leaved stitchwort	*Stellaria longifolia*
common dandelion	*Taraxacum officinale*
early meadow-rue	*Thalictrum dioicum*
white cedar	*Thuja occidentalis*
false miterwort	*Tiarella cordifolia*
basswood	*Tilia americana*
goats-beard	*Tragopogon pratensis*
star-flower	*Trientalis borealis*

hop clover	*Trifolium agrarium*
alsike clover	*Trifolium hybridum*
white clover	*Trifolium repens*
white trillium	*Trillium grandiflorum*
common cattail	*Typha latifolia*
red elm	*Ulmus rubra*
elm A	*Ulmus sp.*
common mullein	*Verbascum thapsus*
blue vervain	*Verbena hastata*
common speedwell	*Veronica officinalis*
maple-leaved viburnum	*Viburnum acerifolium*
nannyberry	*Viburnum lentago*
high-bush cranberry	*Viburnum trilobum*
tufted vetch	*Vicia cracca*
common periwinkle	*Vinca minor*
violet	*Viola sp.*
river bank grape	*Vitis riparia*
prickly ash	*Zanthoxylem americanum*
hairy grass A	
grass B	
sedge C	
sedge D	
sedge E	
thistle A	
unknown L	
unknown M	
unknown P	
unknown P2	
unknown R	
unknown X	
unknown a	
unknown d	
unknown h	
unknown l	
unknown n	
unknown p	
unknown q	
unknown s	
unknown t	